Investment Analysis Benefit Guidelines:
Quantifying Flight Efficiency Benefits

Version 3.0

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Table of Contents

1.0 INTRODUCTION

Increasing flight times in the National Airspace System (NAS) have been and are expected to continue to be a pervasive problem. As demand for air travel continues to grow at a rapid pace, the Federal Aviation Administration (FAA) and the airlines will continually be under scrutiny by the flying public to restore the system and improve overall performance.

This document, the *Investment Analysis Benefits Guidelines: Quantifying Flight Efficiency Benefits* presents a structured methodology for measuring the impact of flight times from expected enhanced capabilities of planned NAS acquisitions. Several FAA acquisition modernization programs are expected to enhance performance by delivering improvements in this area over the next decade.

1.1 Background and Objective

The Investment Analysis and Operations Research Directorate (ASD-400) is responsible for conducting investment analyses and rebaselining major NAS acquisition programs. The Acquisition Management System (AMS) mandates that program benefits are estimated and formally baselined at the investment decision for all FAA acquisition programs. These analyses support the recommendations that are presented to the Joint Resources Council (JRC) for investment decisions.

The objective of this document is to provide guidelines for baselining and measuring one of the benefits components that is frequently embedded in an acquisition's expected user benefits: **flight efficiency**. This document establishes a suggested framework by describing steps that the benefits analyst(s) working on Investment Analysis Teams (IATs) or on rebaselining of a particular program, typically a modernization program, must undertake. The steps will provide a simplified fundamental approach so that benefit claims can be carried forward in the benefits baseline of an Acquisition Program Baseline (APB) and/or applied for post-implementation tracking.

The presentation that follows support: 1) a traditional process leading up to the "official" investment analysis in support of the JRC 2a or 2b decision, and 2) whenever a program rebaseline is required.

1.2 Organization of the Document

This document is organized as follows. Section 2 provides a definition of the *flight efficiency* measure that is used throughout the document. Section 3 presents a framework for conducting the analysis. Six discrete steps are described in general terms. Section 4 presents an approach for quantifying each of the components of a flight. Section 5 presents an example that applies the steps described in Section 3 to complete an assessment. The final section, Section 6, provides a description of the resources available that can support any evaluation in the "flight efficiency" area. This document should be considered a supplement to the *General Guidelines for Conducting the Benefits Analysis Portion of an Investment Analysis* [Ref 1]. There is overlapping information in both documents. It is recommended that the analyst(s) use both documents while conducting the analysis.

2.0 DEFINITION

Flight efficiency refers to the change in block time or gate-to-gate time for a defined set of flights. This measure varies from the traditional way of measuring aviation delays[1]. The measure of flight efficiency will be based on a flight time reduction or a mitigation of the trend from longer block times due to more efficient user operations. The notion of this measure is centered on the ability of a flight to fly within a certain set time. A flight's behavior that develops the flight efficiency metric is a function of what occurs at each segment of the flight: the departure gate, departure runway, top of climb, the cruise phase, beginning of descent, arrival fix, runway threshold crossing, and so forth. Flight efficiency will be measured as follows:

The time it takes an aircraft to pushback from the gate until the time it lands at the gate and turns it's engines off upon arrival at the gate. It is the aircraft's combined taxi-out, airborne, and taxi-in time[2].

3.0 CONDUCTING THE ANALYSIS

A structured framework is needed so user benefits or internal program metrics can be replicated and consistently measured on a recurring basis. Specifically, this document presents basic guidelines to support a more consistent quantification of any purported flight efficiency benefit being claimed for a specific NAS acquisition program (See Figure 1). The following six steps should be applied to develop outcomes for measuring the impact or contribution of the acquisition.

- **Step 1:** Collect and identify the appropriate information and data needed for the analysis.
- **Step 2:** Identify and assess the change or anticipated improvement in the specific user performance attributes affected by implementing and applying the functionalities of the acquisition.
- **Step 3:** Establish a pre-acquisition baseline.
- **Step 4:** Estimate the impact of user performance change upon user operational parameters.
- **Step 5:** Estimate and project the total dollar value from the change in operational parameters in the current and future years.
- **Step 6:** Calculate the estimated present value of alternatives that claim improvement in flight times.

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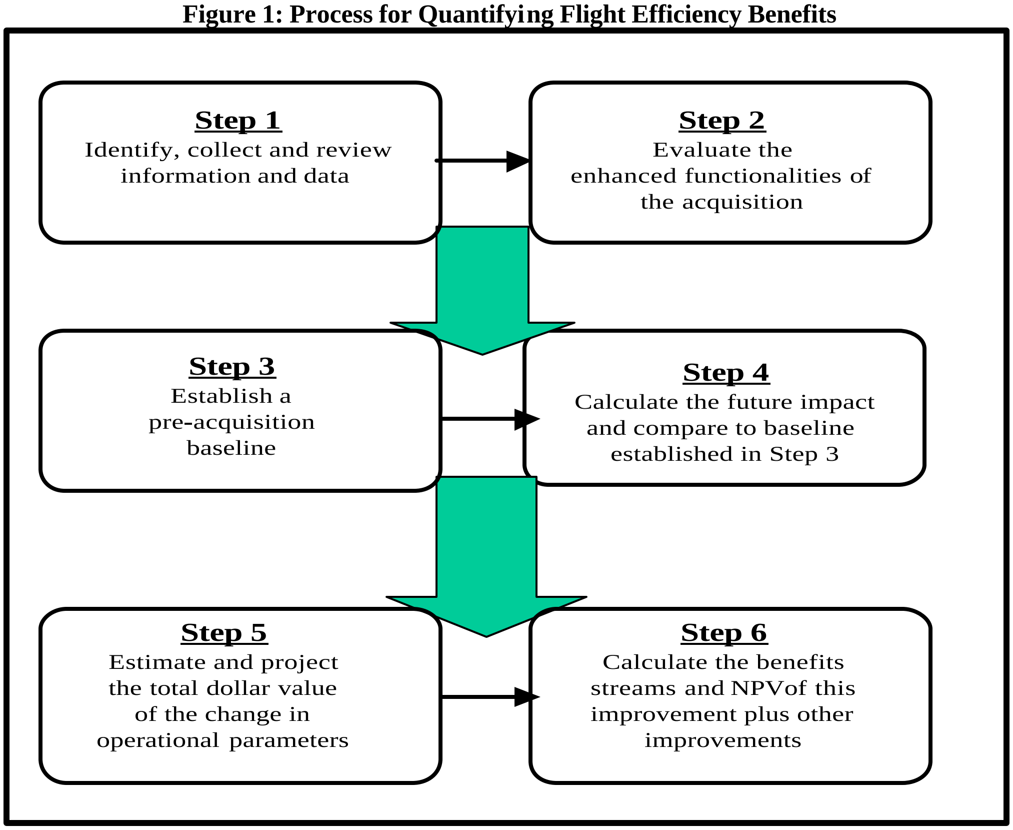
[1] The traditional ways of measuring delay are: 1) per DOT, in the spring 2001 timeframe: the time difference in a flight's actual arrival time and scheduled arrival time from the airline's that submit on-time performance to the DOT, and 2) per the FAA's Command Center (ATCSCC): all ATC induced delays that are carried forward in the OPSNET through the ATCSCC; includes departure, enroute and arrival delays, delays of 15 minutes beyond an "expected time" in any of these phases is considered a delay.

[2] The flight efficiency measure does not include time waiting at the gate. We will consider the "time spent waiting at the gate" as an element of delay. It is the difference in the scheduled departure time and the time the aircraft actually departs or pushes back from the gate.

Figure 1: Process for Quantifying Flight Efficiency Benefits



Step 1: Collect and identify the appropriate information and data needed for the analysis.

The first step identifies and assesses the claimed capabilities that the acquisition expects to provide. This step includes doing a preliminary analysis by evaluating and cross-walking documents such as a program's Mission Need Statement (MNS), Initial Requirement Document (iRD), if they exist, or agency documents such as the NAS Operational Evolution Plan (OEP) and the NAS Architecture document before the IAT formally kicks off. In addition, the Integrated Product Team (IPT), sponsor, and ASD-400 need to coordinate and develop a formal agreement, e.g., a Memorandum of Understanding (MOU) or Memorandum of Agreement (MOA), on any data requirements (as best can be expected) before the IA begins. The data requirements might include tower logs, archived Operational Performance System Network (OPSNET) data or getting access to the tool's operational testing results. Furthermore, pertinent trade studies, including benchmarking studies and any evaluations that have been completed in the recent years should be examined. To ensure this part of this task does not become redundant and superfluous, it is important to examine all the efforts that assess this acquisition's capabilities.

Recent program evaluation efforts that may be useful as part of the literature review process include:

- The work that the Free Flight Office Phase Metrics Team (AOZ-40) has been doing on the semi-annual *FFP1 Operational Performance Evaluations* (June 2000 and December 2000 reports). Specifically, measurements capture changes in enroute time and distance flown of some of the Free Flight program's planned acquisitions for the Traffic Management Advisor (TMA), the passive Final Approach Spacing Tool (pFAST), and the User Request Evaluation Tool (URET).

- Some of the recent studies that have been done in the previous years by MIT Lincoln Labs on the Integrated Terminal Weather System (ITWS). Numerous ITWS evaluations quantify benefits from better runway/airfield management during thunderstorms, adverse wind conditions, poor ceiling and visibility, and arrival and departure transition area management.
- The recent work done with the Safe Flight 21 working group that examined the viability of the Automatic Dependent Surveillance – Broadcast (ADS-B). Generally speaking, whenever possible, it is strongly encouraged to collect and maintain the test and evaluation results through prototyping sites or limited deployment efforts such as the Safe Flight 21 project, which focused on sites in Alaska and the Ohio Valley.
- The capabilities cited in the Satellite Navigation Business Case, February 2001, such as more direct routes to the gate and additional Random Area Navigation (RNAV) tracks for general aviation (GA).
- The NAS OEP, found at *(http://www.caasd.org/nas-evol/)*, is a very useful source to examine. This plan describes the evolution of the NAS and identifies the near- and mid-term commitments to improving the demand-to-capacity imbalance.

Step 2: Identify and assess the change or anticipated improvement in the specific user performance attributes affected by implementing and applying the functionalities of the acquisition.

This step involves the analyst implementing a structured benefits evaluation approach. There are several questions, most of which should be resolved in the MNS that need to be addressed when assessing the claimed improvement. These include:

- What user inefficiencies (more direct routes, more fuel efficient routes, better weather predictions, changes in user procedures, etc.) will this acquisition address?
- How will this acquisition utilize new FAA or Air Traffic Control (ATC) procedures? How will it impact FAA regulations that reduce requirements on user procedures and user time?
- What are the acquisition's additional capabilities that will improve the performance?
- What will the acquisition physically do?
- Who will it affect? What are the current and project equipage rates?
- How many sites are involved? What proportion of the aviation community will benefit from the acquisition?
- How will it impact both the users and providers?
- Are there any patterns that have statistical significance in the historical data?
- Does the data provide a further breakdown of types of delays to solve the problem, i.e., equipment delays, weather delays, volume delays, runways, etc.

The analyst needs to do as complete and rigorous of an internal assessment as possible to give this step clear direction. Refer to Part 10 (page 7 and 8) in *the General Guidelines for Conducting the Benefits Analysis Portion of an Investment Analysis* document regarding checking for double counting and the impact of other programs on the benefits. The General Guidelines document noted above will be referred as [Reference 1] throughout the remainder of this document. Candidate decision processes that impact the performance objective which include optimizing flight planning, load planning, and gate usage need to be assessed. The details developed from this step need to be documented clearly in the Investment Analysis Report (IAR).

Step 3: Establish a pre-acquisition baseline.

This step establishes a pre-acquisition baseline statistically derived from the historical data. It is critical that this baseline, which consists of the applicable flight and/or phase-of-flight time(s), is established before the future scenarios or the alternatives from the "enhanced capabilities" are developed. It is vital that the ground rules and assumptions are identified in the baseline. The baseline, which can be viewed as the situation that would exist if the particular acquisition were not implemented, must be measured thoroughly so an accurate analysis can be delivered. Section 4.0 will present illustrations, using existing operational data, of how to develop this step in sufficient detail.

In this section, along with establishing the ground rules and assumptions, it is critical that the caveats and limitations that define the integrity and accuracy of the benefit estimation are clearly annotated. Misinterpretations in the collected data will unquestionably occur; however, in the aggregate the averages with large sets of events, e.g., number of flights, will be meaningful for the purposes of establishing a baseline. For example, when evaluating flights that file through the North American Route Program (NRP), it may be difficult to map the flights that encountered turbulent weather or were re-routed to the collected data, similarly, it may be difficult or time consuming to adjust for the flights that are eligible or have flown RNAV routes. Also, it is necessary to understand the throughput rates relative to capacity.

For this metric/benefit, the operational domain of the flight efficiency metric is the enroute domain; however, there are dependencies with the terminal area approach/departure and surface domains (gate hold and taxi times) that must be considered. The average times of each of these components (taxi-out, airborne, taxi-in) in the aggregate provide a basis for deriving meaningful average flight times or block times. The benefit recipients must be identified, i.e., what portion of the flying public and what proportion of the scheduled air carriers and commuters will be impacted by the acquisition?

Step 4: Estimate the impact of user performance change upon user operational parameters.

This step captures the differences between the baseline case (established in Step 2), typically, the status quo, and all case(s) that will implement different acquisition alternatives, if applicable, (in some cases the multiple alternatives may give different levels of improvement). The alternative(s) should capture the change in operational parameters from what is currently implemented. The "changes" in the operational parameters could include capabilities such as a reduction in aircraft fuel usage per flight due to additional direct routing, and better predictions in adverse weather conditions or reduction in lateral separation between aircraft tracks.

Whenever a claim of a flight time reduction or an alleviation of a flight time increase will provide a cost savings, it is vital to reference the relevant documents, information sources, and completed studies. Are the estimates of the number of users that could be potentially impacted from the acquisition supportable? In other words, are we looking at only domestic air carriers and commuters, the operational time the acquisition is operational, aircraft with certain types of equipment, etc. What is the utilization rate or the number of hours the tool is expected to be operational? What are the equipage rates? Is there a basis of estimate from this predicted rate?

Candidate parameters that may be considered in this analysis include: the frequency of instrument meteorological conditions (IMC) and visual meteorological conditions (VMC),[3] type of aircraft, time of day performance, season, etc. This step entails comparing the results of the baseline case established in Step #2 using historical data, then drilling down to a lower-level perspective as part of the data evaluation process and projecting the future impact. Forecasting techniques noted in Section 4.2 are discussed. This step then involves making a preliminary rough-order-of-magnitude (ROM) future estimate from the capabilities identified in Step #2. The data sources, tools, and reference documents are noted in Section 6.

Step 5: Estimate and project the total dollar value from the change in operational parameters in the current and future years.

This step includes the extrapolation of the results from Step #4 to reflect the expected representative population, i.e., the NAS, all commercial flights, all commuter flights, GA population, the planned sites, whether they are selective airports, the traffic through Air Route Traffic Control Centers (ARTCCs), etc[4]. The results need to be annualized based on the evaluation of a subset of a few sites that have preliminary findings. The extrapolation can be very complex when projecting from one day to a year, and limited number of sites to all sites. For example, what factors need to be considered when transforming the preliminary test results of ADS-B for the Ohio Valley and Alaska compared to the Northeast United States or pFAST from Dallas/Ft. Worth (DFW) to other sites that have had a very limited amount of evaluation.

Within this document, it is virtually impossible to give a simple cookbook answer for generalizing the extrapolation. Yet, certain basic questions that have been raised from the assessment in Step #2 can help characterize the factors that ultimately drive the logic that comprise the ground rules and assumptions in the extrapolation.

These extrapolation factors include, but are not limited to, the following: number of impacted users, usage rate of the tool(s), the fleet mix (aircraft type), the airport attributes (number of

[3] ASD-400 maintains both the historical climatological data and the hourly surface weather observations for most of the major airports.

[4] The extrapolation methodology from limited deployment to full deployment is generally up to the IAT Benefits group. Regardless of how the extrapolations are done, it is important to annotate all ground rules and assumptions.

runways and type of operations), the airspace attributes, traffic growth, and so forth. It needs to be clear where and when the acquisition will/will not make an impact and if the data sampled is representative of an expected year. The Terminal Area Forecast (TAF), which is provided through APO-130, should be used to reflect the total number of current and projected operations.

The fleet mix at a high level also can be garnered from the TAF, at a more detailed level the Enhanced Traffic Management System (ETMS) or Consolidated Operations and Delay Analysis System (CODAS) must be used. For example, the number of operations at O'Hare International Airport (ORD) accounts for X% and has a "weighted contribution" of Y% for the sites being considered.

Once the extrapolation is completed, the next step is to monetize the benefits. There are two steps: 1) computing the airline direct operating costs (ADOC), and 2) computing the Passenger Value of Time (PVT). Table 1 shows an example of ADOC for a 737-400 and 737-500, per APO-98-8 [Ref. 4].

Table 1: Summary of ADOC Costs

AC Type	Source Type	Hour Type	Load Factor	Seats	Crew $/HR	Fuel $/HR	Maint $/HR	ADOC $/HR	Rentals $/HR	Deprec $/HR
B-737-4	Carrier	Airborne	0.680	144	999	629	309	1,937	694	88
B-737-4	Carrier	Block	0.680	144	845	531	261	1,637	586	74
B-737-5	Carrier	Airborne	0.686	110	663	566	464	1,693	384	139
B-737-5	Carrier	Block	0.686	110	552	471	386	1,409	319	115

The first step in computing the total dollar value savings involves estimating the ADOC of avoided increased flight time from the acquisition's expected capability. For example, if the estimated flight timesavings is 2 minutes, the ADOC savings would be ($1,937÷60 minutes)* (2 minutes saving) or $64 of ADOC saved per flight. While this $64 per flight may not sound like much, if 500 flights are affected per day, then the daily cost savings are approximately $32,000 or over $11M annually. An adjustment needs to be made to account for any potential ground cost savings. The suggested way is to keep the crew and maintenance constant while accounting for the fuel savings. A reasonable ground-to-air dollar factor that was applied in the recent FFP2 Investment Analysis Study Report for the fuel cost alone was 33%.

The second step involves computing the PVT. Table 2 below shows current data from APO-98-8 [Ref. 4].

Table 2: Breakdown of PVT (1995 dollars)

Category	Recommendation	Sensitivity Range Low	Sensitivity Range High
Air Carrier			
Personal	$19.50	$16.70	$25.00
Business	$34.50	$27.60	$41.40
All Purposes	$26.70	$21.90	$32.90
General Aviation			
Personal	$26.30	NR	NR
Business	$37.50	NR	NR
All Purposes	$31.50	NR	NR

In general terms, it is assumed that load factor is applied to the following categories of aircraft as shown in Table 3 below.

Table 3: Aircraft Capacity and Utilization Factors [Source 4]

Aircraft Category	Seat Capacity	Load Factor
Scheduled Air Carriers	162	70%
Commuters	30	52%
Air Taxi	6.6	44%
General Aviation	5.4	49%

Recommended hourly values are presented for both air carrier and GA for personal, business, and all purposes categories. The hourly air carrier all purposes value is $26.70 per hour/per person; the hourly GA value is $31.10 per hour/per person. Note: the costs above must be adjusted to the Office of Management and Budget's (OMB) 2000 Gross Domestic Product (GDP) deflator per Circular No. A-94 [Ref. 6].

A factor of approximately 6.3% (1.0 ÷ 941), based on the difference from 1995 to 2000 (per the GDP deflator or Consumer Price Index (CPI)), needs to be adjusted for conversion into FY00 U.S. dollars.

Step 6: Calculate the estimated present value of alternatives that claim improvement in flight times.

All dollar values of benefits must be expressed in the same year dollars, "constant dollars". If all dollar values are not expressed in the same year, then the effects of inflation on dollar values in different years will result in a particular benefit having one dollar value expressed in year X dollars and another value expressed in year Y dollars. This can lead to confusing and misleading benefit assessement results. Also, two benefits expressed in different years cannot be combined to yield a total benefit. If there are other benefit categories, then each category needs to be aggregated into the life cycle benefits stream.

Using the OMB-specified discount rate of 7%, apply the following formula.

$$\sum_{n=1}^{20} \frac{B_n}{(1+.07)^N}$$

where B_n is the benefit year n, n is the first year of the life cycle, e.g., 2001 and $n = 20$ is the last year in the life cycle, e.g., 2020.

Table 4 shows the discount factors that should be used when computing the Net Present Value (NPV). This step needs to be completed when any other applicable benefits category is computed.

Table 4: Discount Factors

DISCOUNT FACTORS (7% Rate)		
Year	***n***	**Discount Factor**
2001	0	1.00
2002	1	.935
2003	2	.873
2004	3	.816
2005	4	.763
2006	5	.713
2007	6	.666
2008	7	.623
2009	8	.582
2010	9	.544
2011	10	.508
2012	11	.475
2013	12	.444
2014	13	.415
2015	14	.388
2016	15	.362
2017	16	.339
2018	17	.317
2019	18	.296
2020	19	.276

4.0 APPROACH

The flight times need to be developed by evaluating historical data from sources such as CODAS, Airline Service Quality Performance (ASQP), ETMS, and the Official Airline Guide (OAG). Several attributes and views of these data can be evaluated through ASD-400's Performance Monitoring Analysis Capability (PMAC) tool, the associated processed files, or any other organization that maintains the relevant data. A complete description of the data files that reside in ASD-400 can be found in the *Performance Monitoring Analysis Capability V3.0 Addendum Document*, *October 1, 2000.* Other organizations with useful data include: APO, (*http://www.apo.data.faa.gov/faacodasall*); Air Traffic *(http://atcscc.faa.gov/);* and Department of Transportation (DOT) *(http://www.dot.gov/airconsumer/).* PMAC has several data sets dependent on the ASQP, the airlines reported information to DOT and CODAS, that can give the analyst a breakdown of the historical and current block times, or by phase-of-flight (airborne times and taxi-times) in a timely manner. Each of these times needs to be understood and developed for defining the baseline. The next three sub-sections 4.1, 4.2, and 4.3 provide high-level illustrations for measuring the flight times.

4.1 Gate-to-Gate (Block) Time

An example of the scheduled block time and actual block time for all flights (using October 1998 and 1999 as an illustration) into Boston-Logan International (BOS) is presented below in Table 5. For example, associated block times for Atlanta Airport (ATL), DFW, Washington National Airport (DCA), and ORD to BOS for 1998 through 1999 are presented. The actual block times and actual airborne times are assembled from the ASQP; the average filed flight plans is from the CODAS. The analyst must identify the applicable city pairs, which are dependent on the projection of the operational sites, as part of the baseline development process.

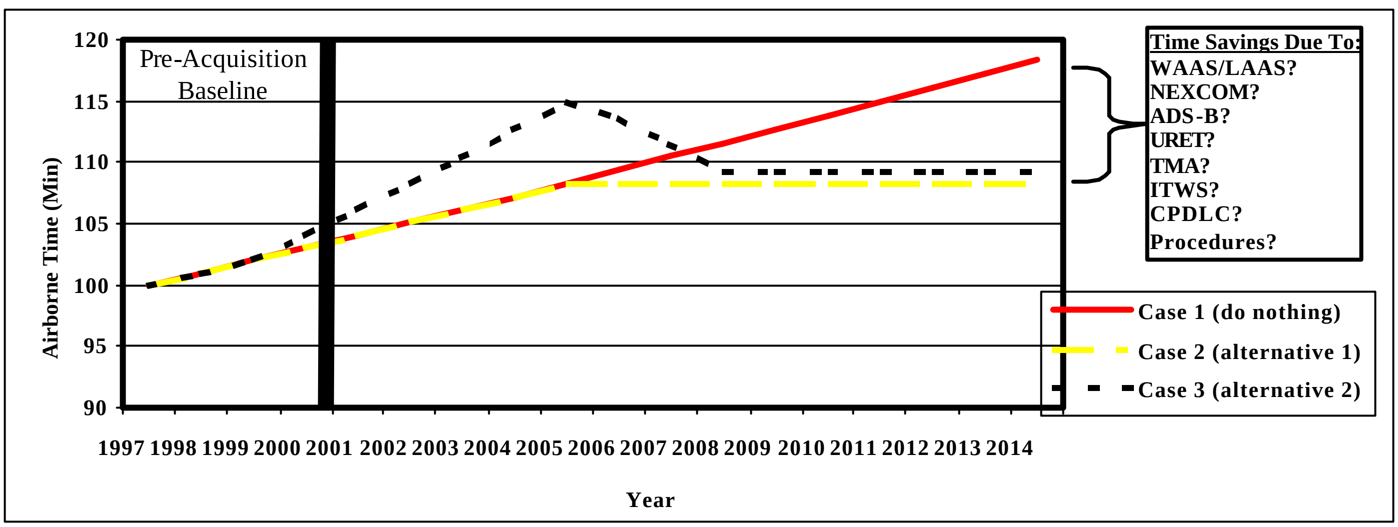
Table 5: Sample of Scheduled Actual Block Times

	Avg. No. of Daily Flts	Scheduled Block Time		Actual Block Time		Actual Airborne Time		Filed Flight Plan	
City Pair		Oct 1998	Oct 1999	Oct 1998	Oct 1999	Oct 1998	Oct 1999	Oct 1998	Oct 1999
ATL-BOS	14	147.0	87.8	143.0	84.5	117.5	63.0	117.6	54.0
DFW-BOS	15	147.7	87.9	152.3	89.3	126.0	65.1	124.2	58.1
DCA-BOS	28	215.6	134.3	207.6	131.2	182.3	106.6	182.4	111.0
ORD-BOS	30	218.7	133.3	215.3	135.2	189.6	110.0	190.3	110.5

While the definition of flight efficiency reflects the actual times, the time that each carrier strives to meet or exceed to meet its on-time performance is the scheduled block time. It is the difference between the departure and arrival time per the OAG. Actual flight times will always try to fly its scheduled time. Note how close the scheduled versus actual times are for some of the origin-departures (O-D) pairs. For O-D pairs, the times frequently vary. Scheduled block times vary significantly depending on the time of day, aircraft type, and history of performance for a given flight. For example, a morning flight from ATL to Charlotte (CLT) has a 52-minute scheduled block time, whereas an evening flight from ATL to CLT has a 62-minute scheduled block time.

Figure 2 below illustrates three hypothetical cases of how future block time could be projected from the pre-acquisition baseline that is based on the performance from 1997 to 2000. The figure is broken down as follows:

Figure 2: Illustration of Block Time Projections - Three Cases



Case 1: The "do nothing" case, i.e., if the acquisition is not implemented and the FAA continues to support programs in the Capital Improvement Plan (CIP). It shows a 1% increase in block times through 2015, consistent with the trend observed from 1997-2000.

Case 2: Alternative 1, this is where the relevant city pairs and the equipped aircraft consists of 50% of the total commercial flights, the block time increases by 1% through 2005, then remains at a steady state through the life cycle beginning in 2006.

Case 3: Alternative 2, shows that the block time has been increasing by 2% per year over five impending years (2001-2005), drops by 1% for the next three years (2006-2008), then remains steady from 2009-2015.

The future block time's assumptions are hypothetical for illustrative purposes. These future times need to be projected or estimated through the various forecasting techniques and simulation modeling after the baseline is established through the historical data.

When *projecting future block times*, several parameters must be considered in the analysis. They include any combination of the following:

- Sector capacity (monitor alert parameter thresholds) – *Source:* Air Traffic Control Systems Command Center (ATCSCC)
- Airport capacity – current and future capacities with runway and procedural improvements and Communications, Navigation, and Surveillance/Air Traffic Management (CNS/ATM) enhancements – *Source:* FAA Capacity Benchmarks and ASD 2000 Airport Capacity Survey
- Flight plans – *Source:* ETMS
- Demand – *Source:* OAG flight itineraries (current scheduled flights) and TAF (current and future operations and enplanements)
- Fleet mix – *Source:* ETMS, OAG
- Utilization rate – the departure and arrival rates relative to the airport capacity in varying weather conditions
- Aircraft type – *Source:* Air Transport Association (ATA), Flight Service Standards (AFS), and Office of Aviation Policy and Plans (APO)

4.2 Airborne Time

A subset of the calculated block time or the gate-to-gate time that can be evaluated is the *airborne time*. Typically, for an average domestic flight, the airborne time accounts for 80-85% of the total flight time, e.g., in 2000 the average (median) block time was 125 minutes, the median airborne time was 105 minutes.

The first check the analyst can make is see if there has been a change in variability. As an illustration, let's assume that the airborne time in 1997 is normally distributed with a mean of 100 minutes, with a standard deviation of 4.1 minutes. The standard deviation is defined as follows:

$$\text{Standard deviation} = \sqrt{\frac{n\sum X^2 - (\sum X)^2}{n(n-1)}}$$

where ***n*** is the number of events, in this case, flights and ***x*** is the airborne time of each flight. As an example, if there are five flights (that fly most days during the year to an airport) with average airborne times of 95, 97, 100, 103, and 105 minutes, a mean of 100 minutes, the standard deviation is 4.1. Let's say in the following year in 1998 during prototype operations over the year at the same airport for the same five flights, the first two flight's airborne times decrease from 95 to 93 minutes and 97 to 95 minutes, and the last two flight's airborne times increase by 2 minutes from 103 to 105 minutes and 105 to 107 minutes, then the standard deviation becomes 6.1 minutes with the mean still remaining at 100 minutes. What this implies is the variability is larger and the predictability may not be as accurate as it was previously when the standard deviation was smaller. Therefore, there is a potential benefit if the acquisition can maintain the better predictability as was observed in the prototype operation.

An example of the average actual airborne time compared to the average filed flight plan time for all flights (from the ETMS in October 1998 and 1999) into BOS is presented below under column B in Table 6.

Table 6: Airborne Phase Times

	Avg. No. of Daily Flights	Actual Airborne Time		Filed Flight Plan		Difference Actual Time – Filed Time	
City Pair		Oct 1998	Oct 1999	Oct 1998	Oct 1999	Oct 1998	Oct 1999
ATL - BOS	14	117.5	126.0	117.6	124.2	-.1	+1.8
DFW - BOS	15	182.3	189.6	182.4	190.3	+.1	-.7
DCA - BOS	28	63.0	65.1	54.0	58.1	+9.0	+7.0
ORD - BOS	30	106.6	110.0	111.0	110.5	-4.6	-.5

These data in the table can be examined in several ways; these are merely two high-level views presented for illustrative purposes. It gives the analyst a sense of an expected time baseline. Of course, there are irregularities and outliers in the data, but collectively for a large set of city pairs, the values can give a reasonable portrayal of the performance change. The analyst needs to be aware of other variables, such as the growth in demand and the arrival and departure utilization factors (demand/capacity) that can impact the values. *Key point* - it is up to the analyst whether he/she wants to use one year or multiple years to establish an initial baseline (current state) value.

Evaluating multiple years of historical data is the best way of establishing the starting point for the airborne or block time performance. Figure 3 and Table 7 illustrates this using three years of data. Figure 3 below shows a slight increase in both airborne and block times with linear extrapolations. The analyst can look at either the 25th percentile or average times to derive an "optimistic" baseline. It also may be considered as a lower bound of an "efficient flight".

Simplistically, based on the average of the 25th percentile, (which may be considered an expected standard to attain) the airborne times average about 101 minutes over the three years. As the airborne time has increased by 2-3 minutes, the demand also has increased by 3% in this timeframe; therefore, a normalized statistical baseline can be developed from multiple years that will enable projections to be made accordingly.

Figure 3: Sample of Airborne and Block Times

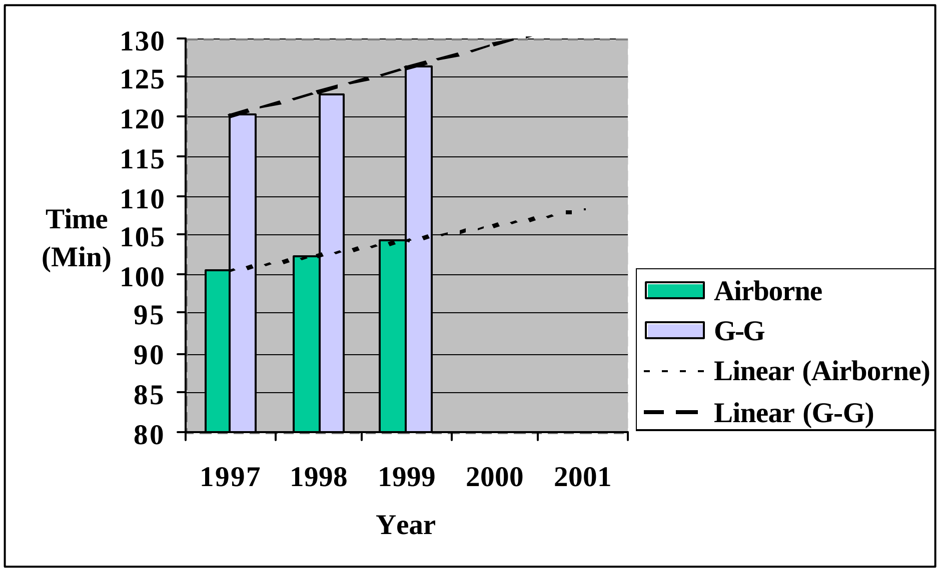


Table 7: Trends in Performance

Phase-of-Flight	1997 (avg)	25th %tile	1998 (avg)	25th %tile	1999 (avg)	25th %tile	% Change (97-98)	% Change (97-99)
Airborne	100.4	99.6	102.3	101.3	104.3	103.1	+1.9	+3.9
Gate-to-Gate	120.3	119.1	122.9	121.4	126.3	124.2	+2.2	+5.0

The derivation of the *current baseline* of airborne times for each city pair should be done as follows:

1) <u>Current airborne time</u>

The following are two preferred measurement options:

a) Actual airborne time = *Average of actual wheels-on time minus actual wheels-off time. Source:* ASQP (1995 to present), CODAS (1998-2000), or ASPM (after December 2000) for all flights.

b) Planned airborne time = *Average of the filed estimated time enroute. Source:* CODAS, ASPM, and ETMS for domestic flights; ETMS and ASPM for international flights.

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The derivation of the airborne times based on *future scenarios* from the different alternatives should be done in one of the following two ways:

2) <u>Projected airborne time</u>

a) *Average of predicted wheels-on time minus predicted wheels-off time based on future states of the system. Source:* Detailed Policy Assessment Tool (DPAT) or NAS Performance Analysis Capability (NASPAC) simulation model.

   DPAT and NASPAC are discrete-event simulation models that can model current and future performance of the NAS by adjusting key parameters such as demand and airport capacity for 80 of the busier airports.

b) Average of any of the below accepted forecasting techniques.

The basic idea of forecasting is to find a mathematical formula that will approximately generate the historical patterns in a time series. Forecasting techniques of any historical time series (e.g., a sequence of monthly data points over multiple years) include: 1) moving average procedure, 2) exponential smoothing procedures, 3) cyclical forecasting, and 4) the Box Jenkins method. These techniques should cover the trends, which may be either linear or nonlinear (curved). A trend is a long-run, low frequency, slow evolution of variables, e.g., airborne times. There are other ways of measuring trends; the four above techniques are suggested approaches that are easy to generate given a sufficient number of data points.

The moving average technique is simply an average that moves with time. As a new time period advances, then the new value is added into the average calculation and the oldest data point is dropped out of the average calculation. With exponential smoothing, the most recent values have a greater weight in determining the forecast for the next period. Cyclic forecasting is another method. There are four components of cyclic forecasting: trend, seasonal component, cyclical component, and random variation. The final method, the Box Jenkins method (referred on Table 1, evaluation F in Ref [1]) is the most sophisticated method. This method typically requires 40 to 50 equally spaced periods of data. This method requires a plot of the original data and is adjusted to form a stationary series, one whose values vary more or less uniformly over a fixed level of time.

The next version of this document will provide an illustration (case study) of each of the four noted forecasting methods. A standard Forecasting textbook can be used for understanding how and when to apply the tests. There is a wide range of forecasting software available. One tool, Excel 2000 under the Tools/Data Analysis option (if the Analysis Toolpak is installed), can generate results from the various techniques. The forecasting section in EXCEL applies the above techniques except the Box Jenkins method.

To better understand the behavior of the key data variables that impact flight efficiency such as number of operations, the analysts also can employ multi-variant (independent variables such as demand/capacity ratio, change in operations) regression analysis that impact future trend lines.

This is a good technique for accessing which factors to include in the time series analysis. **Note: predicting a change over time or extrapolating from present conditions to future conditions is not the function of regression analysis.** To make estimates of the future flight efficiency trends, use one of the four aforementioned techniques or conduct simulation with DPAT or NASPAC as noted in 2a above.

The Logistics Management Institute (LMI) notes in Ref. [22] method in Section 5.3 that a general linear model of block time can be applied. The parameters include the estimated future arrival utilization ratio, the quotient of arrival demand and arrival capacity and the departure utilization ratio, the quotient of departure demand and departure capacity. It is left to the analyst to investigate if this general linear model is relevant for the application.

4.3 Taxi Time

The other component of the gate-to-gate time that is not captured in the airborne or filed flight time is the *taxi time*. The best way to get a general sense for the taxi-in and taxi-out trends can be derived by examining an airport's (this applies to the busier airports) frequency distribution developed from ASQP that is generated for each year and resides in PMAC. For example, a distribution based on 1999 events from the ASQP is as follows. An average (median) taxi-in and taxi-out time as well as the pushback delays (difference in actual pushback from the gate and the actual pushback time) can be used from each annual file to baseline the time spent on the ground. Table 8 below displays a rollup of the recorded taxi-out distribution times at ATL for 1995 through 2000 from the ASQP. The files with the more detailed information are available upon request for all major airports.

Table 8: Taxi Time Illustration

ATL – Cumulative Distribution Actual Taxi-Out Times (%)						
Time	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
10	18.3	17.3	14.8	11.5	10.0	6.7
15	47.9	51.5	48.6	44.2	42.0	35.2
20	69.3	75.0	73.3	69.5	67.9	64.6
25	83.9	88.7	87.8	84.7	83.9	81.0
30	92.4	95.1	94.8	92.6	92.4	90.6
Median (min)	**15-16**	**14-15**	**15-16**	**16**	**16-17**	**17**

If the analysis that developed the baseline (which should be annotated in the Investment Analysis Study Report and reflected in the APB) is mature and well established with a sound basis of estimate, then the IAT needs to apply its judgment if the parameter's key drivers have been adequately measured. For compressed IAs with a short turnaround time, it will be very difficult to analyze and understand the impact of some of these parameters unless the benefits analysis is coordinated and in progress well before the official kickoff of the IA. In cases such as an FFP1 and FFP2 acquisition, like URET, where extensive analysis has been done, it is up to the analyst's discretion how much verification and validation needs to be done. However, all caveats and swing variables or limitations need to be understood and documented as part of the analysis. Furthermore, all sensitivities in the parameters need to be documented.

5.0 EXAMPLE

This example, which is presented at a high level, is solely for illustrative purposes. A problem is presented with a brief discussion of the approach.

Problem

A NAS modernization program feels that its acquisition can reap substantial benefits in the future. Preliminary results from evaluations of prototype systems at three selected sites have shown promising results on a limited number of flights during the busier periods of the day. There are currently two alternatives the IPT is considering; there are slight differences from the operational capabilities and the sites planned for implementation. Over the past five years (1996-2000), block times between several of the busier city pairs have increased over 5% from an average of 100 minutes to 105 minutes, while the demand (number of operations) also has been increasing at a rate of 5%. At the same time, very minor procedural improvements and limited airport improvements have been made at the candidate airports, typically, the busiest airports in the NAS. What are the expected flight efficiency benefits from the two alternatives relative to a "Do Nothing" (reference) case?

Approach

From the above problem, at the onset, it is necessary to address two questions:

1) What is the best way to establish a baseline or a reference case, i.e., a fixed standard, so future benefits from enhanced functionalities can be credibly estimated?
2) How are benefits projected through the acquisition's life cycle?

The six-step process described in Section 3.0 can be combined into three distinct parts:

1) Preparatory work and baseline development
2) Future operational assessment
3) Monetizing the results

Part 1 involves the preparatory work. This entails conducting a literature search and assessing the program's capabilities (Steps 1-2), then developing a baseline of the flight performance from historical data. Part 2 expands on this baseline estimation from the performance of the current capabilities and projecting the future impact (Steps 3-4). Part 3 entails monetizing the differences between the reference case or "do nothing" case and the alternatives (Steps 5-6). This includes evaluating the expected performance over the life cycle to determine if there is either a reduction, steady state, or a slower increase than what the expected trend from what is presently being observed in the NAS. An explanation of each step follows.

Part 1: Preparatory Work and Baseline Development

Data Identification and Collection: Assessing benefits require the identification, collection, and manipulation of a wide range of data sets and documents. Specifically, for the flight efficiency analysis, there are several data sets noted in Section 4.0 that can assist an analyst as he/she begins the analysis. The relevant program documents such as the MNS, iRD, Architecture documents, the OEP, and any studies need to be collected. This step will establish a pre-acquisition accountability of the performance.

There are several checks the analyst can use to identify good/bad days for computing a lower percentile of the airborne time or the estimated time enroute as was presented above in Table 5. The easiest way, as a first step, is to view the **APTYYMM.*, APTYY.*, NASYYODMAP.*, NASYYMM.***, and **NASYY.*** files maintained in ASD-400's internal data management tool, the PMAC[5]. These files contain the airborne and block times for each day from 1995 to present. The analyst can determine the "good performance" and "bad performance" days in the NAS from this data. An illustration of five weekdays in August is provided below in Table 9. An analyst can see that on Monday, August 2, 1999, less airborne and gate-to-gate time and delay occurred than on Thursday, August 5, 1999, by 2 to 5 minutes, respectively. Also, on August 2, 96% of the flights arrived less than 15 minutes beyond their scheduled block times versus 91% on August 5th. Perhaps the projected benefits can consider a better likelihood of good performance days like August 2nd. After this view is done, the analyst can evaluate the distributions of the flights on the "good days" and the "bad days."

Table 9: Block Time Illustration

Date	Airb Min	Avg Airb Min	G2G Min	Avg G2G Min	G2G Delay Min	Avg G2G Del	# of Flts.	G2G Del. (# >0 Min)	G2G Del. (<1 min)	G2G Del, (1-5)	G2G Del. (6-10)	G2GDel (11-15)	G2GDel >15	T-Out Min	T-In Min
990802	1589900	103.2	1919513	124.6	41736	2.7	15405	5008	67%	16%	8%	4%	4%	15.2	6.3
990803	1594775	103.5	1936492	125.6	51637	3.4	15414	5551	64%	16%	9%	5%	6%	16.0	6.2
990804	1606159	104.5	1954680	127.1	65928	4.3	15378	6286	59%	18%	10%	5%	8%	16.4	6.3
990805	1615867	105.2	1970618	128.3	77336	5.0	15366	6401	58%	17%	10%	5%	9%	16.8	6.3
990806	1615488	103.9	1956277	125.9	49172	3.2	15544	5878	62%	18%	10%	5%	5%	15.7	6.3

Data tables, which contain monthly summary reports of scheduled flights for several city pairs, have been developed from the CODAS. For example, from a high-level view an analyst can observe that flights from ATL to BOS in January 1998 had an average scheduled block time of 142 minutes, average actual block time of 145 minutes, and average airborne times of 120 minutes with the predicted estimated time enroute averaging 118 minutes. The analyst then needs to drill down by comparing performance within the same month by day-of-the-week, time of day, etc.

The statistical tests noted in Ref [1] provide an excellent summary for isolating patterns and determining if there is an "improvement in the metric", i.e., block time or any of the phases-of-flight: taxi-out, airborne, or taxi-in time. Though the tests are portrayed as tests for post-

[5] See Performance Monitoring Analysis Capability V3.0 Addendum Document, Appendix A for a list of tables the analyst can access.

implementation assessment, they can be applied for testing the statistical significance during the development of a baseline. For example, test 1, a custom, distribution-free prediction limit test is appropriate for testing at least 9 and 19 data points at the 5% and 10% significance levels.

Part 2: Future Operational Assessment

Once the current state of the system is measured from Part 1, then the future impacts of the two alternatives need to be quantified through the duration of the life cycle as discussed in the previous sections. Multiple scenarios (most likely, best case, etc.) may be necessary to compute for each acquisition alternative. It is inevitable that the projected traffic at the major airports will continue to increase. The data source that should be used for measuring the projected future traffic is the TAF. ASD-400 receives the TAF from APO and portrays the information through two files: **TAFACE.*** (operations with growth rates) and **TAFENP.*** (enplanements with growth rates). The TAF contains all enplanements and operations by air carriers, air taxi/commuters, military, and GA through 2015. Furthermore, the candidate sites, operational time, set of aircraft impact per the equipage rate, type of operations, etc. need to be considered as the future scenarios are developed for each alternative.

Additionally, the future airport capacities and sector capacities (the monitor alert parameter thresholds from the ATCSCC) need to be understood relative to the expected demand. An analyst can use a few sources for these estimates. They include the Airport Capacity Enhancement (ACE) Plan and the 2000 Airport Capacity tool developed and maintained by ASD-400. Additionally, the Future Demand Generator (FDG), a component of the DPAT model, estimates the increase in hourly arrivals and departures at different airports based on the change in the current scheduled demand from the TAF.

Part 3: Monetizing the Results

Once Parts 1 and 2 are completed, it is necessary to estimate the total dollar change (cost avoidance) over the life cycle of the acquisition from each alternative. The attributes that generated the benefits for this user component should be presented so it is obvious how the dollars were generated. For example, Table 10 below presents the number of flights affected and annual hours saved in both the air and ground phases. The relevant ADOC cost factors applied in both the air and ground phases must be identified. In addition, the fleet mix (percentage of air carrier, air taxi/commuter and type of aircraft at each airport) needs to be gathered from the TAF or one day from the ETMS. The ADOC value, which will vary at the different airports, must be noted, e.g., $2,500 per airborne hour and $800 per ground hour.

Table 10 below illustrates five years of estimated flight efficiency benefits. For illustration purposes, Alternative 1 benefits an additional 500 affected flights per day in each subsequent year, ranging from 2,000 affected flights per day in 2001 to 4,000 affected flights per day in 2005. Also, a factor of .95 is applied to reflect the lower number of weekend flights over a 365-day period. Similarly, Alternative 2 has an additional 750 affected flights per day in each subsequent year. From the "do nothing" scenario, Alternative 1 shows a cost savings from the acquisition of $39M over five years; Alternative 2 has a cost savings of $45M. This type of illustration needs to be rolled up to the higher level formats presented in the APB. Note: PVT is not presented in this example.

Table 10: Benefits Comparison Between Acquisition Alternatives: Flight Efficiency Illustration

Comparison Between Two Alternatives (Most Likely Case)											
	Alternative 1 Attributes			Alternative 2 Attributes			Benefit Results				
Year	# of Hrs Saved in Air	# of Hrs Saved on Grd.	Annual # of Affect Flts. (M)	# of Hrs Saved in Air	# of Hrs Saved on Grd.	Annual # of Affect Flts. (M)	Disc Factor (7%)	Alt 1 Ben. in Yr. ($M)	Alt 1 PV in Yr. ($M)	Alt 2 Ben. in Yr. ($M)	Alt 2 PV Ben. ($M)
2001	1156	2890	.693	1156	2890	.693	1.00	5.2	5.2	5.2	5.2
2002	1445	3612	.867	1589	3973	.953	.935	6.5	6.1	7.2	6.7
2003	1734	4334	1.04	2023	5057	1.21	.873	7.8	6.8	9.1	7.9
2004	2023	5057	1.21	2456	6140	1.47	.816	9.1	7.4	11.1	9.0
2005	2312	5779	1.39	2890	7224	1.73	.763	10.4	7.9	13.0	9.9

6.0 RESOURCES

It is critical that the team identify the resources, including data sources, tools, and reference documents for both developing a statistical baseline of the "do nothing" case and projecting the benefits. As previously annotated, this needs to be done early in the process during Step 1.

6.1 Data Sources

Flight efficiency times will be baselined from historical data using FAA and DOT sources. The sources include DOT's ASQP data, the FAA's CODAS, the Airline Service Performance Metrics (ASPM), and the ETMS. Performance from city pairs that have a significant number of flights, which have been baselined from historical data, will form the basis of the analysis. It addresses the single-flight perspective most readily. Also, results derived from the operational data at various prototype sites, such as what the Free Flight Office and Lincoln Labs, in support of the ITWS program, have been doing are recommended whenever possible.

6.2 Tools

Besides applying parametric analysis to make projections from the baseline, there are different candidate tools that can be applied to support some of the future estimates. The applications include utilizing NAS simulation models, NASPAC[6] and DPAT, noted in Section 4.2, developed by MITRE/CAASD that has recently been applied and maintained by ASD-400. Both tools can predict future performance given changing parameters such as airspace, airport capacity, and demand. They are both considered macro-analysis tools that evaluate system-wide impacts of local and national changes for future scenarios.

The future scenarios reflect anticipated changes such as demand and airport capacity from runway improvements and CNS/ATM acquisitions. For a high level of granularity, it is suggested that the analyst work with the IPT early in the process to understand the results and any ongoing or completed detailed site-specific operational analysis. It is necessary for the analyst or the IAT to understand the strengths and limitations of applying and implementing a model such as DPAT.

[6] Both DPAT and NASPAC can provide future projections of flight times given changes in airport capacity, equipage, airspace capacity, routes, and demand.

6.3 Reference Documents

There are a wide range of data sources and reference documents that the analyst(s) can refer to during the literature search and the analysis phases when developing and tracking this metric or rebaselining the user benefits. They include:

1. Cohen, Stephen, Guidelines for Conducting The Benefits Analysis Portion of Investment Analysis, Federal Aviation Administration, September 30, 2000.
2. Harball, Alice, Enhancement of FAA's Capability to Estimate the Benefits of NAS Modernization Programs, MASTER PLAN, Federal Aviation Administration, August 1, 1999.
3. Cost, Benefit, and Risk Assessment Guidelines for RE&D Investment Portfolio Development, October 1998, Source ASD-400.
4. Economic Values for Evaluation of Federal Aviation Administration Investment and Regulatory Programs, FAA-APO-98-8, June 1998.
5. Economic Analysis of Investment and Regulatory Decisions – Revised Guide, FAA-APO-98-4, January 1998.
6. Office of Management and Budget, Circular No. A-94, Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs, October 29, 1992.
7. Airline Metric Concepts for Evaluating Air Traffic Service Performance CNS/ATM Focused Team, November 1997.
8. FFP1 Performance Metrics: An Operational Impact Evaluation Plan, Version 1.0, August 12, 1999.
9. FFP1 Performance Metrics Results to Date – June 2000 Report, June 2000,
10. Free Flight Investment Analysis Study Report, Coordination Draft, Version 0.7, October 2000.
11. Initial Report of the Safe Flight 21 Cost Benefit Subgroup, Volumes 1 and 2, May 2000.
12. Air Traffic Services Performance Plan for Fiscal Years 1998-2000.
13. Evaluating Benefits of a Change in NAS Performance: How to Include Cost and Revenue Implications, MITRE, September 1999.
14. Characteristics of Aviation Excess Costs, MITRE, September 1999.
15. System-Wide Estimate of Excess Air Carrier Costs, MITRE Technical Report, September 1998.
16. Cost Benefit Analysis of the Integrated Terminal Weather System (ITWS), March/April 1995.
17. Order 7210.55A – Operational Data Reporting Requirements, February 6, 1998.
18. 2000 Airport Capacity Surveys, ATP-100 and ASD-100.
19. A Simplified Approach to Baselining Delays and Delay Costs for the National Airspace System (NAS), Interim Report 12A (DCN-R80406-02), May 1999.

20. Office of Inspector General Audit Report, Air Carrier Arrival Data, Department of Transportation, Report Number FE-1998-103, March 30, 1998.

21. The Office of the Inspector General Audit Report, Air Carrier Flight Delays and Cancellations, July 25, 2000.

22. A Method for Forecasting Commercial Air Traffic Schedule in the Future, LMI, NASA/CR-1999-208987, January 1999.